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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Development of a Shipbuilding Simulation Process Modeling Database

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
Newport News Shipbuilding

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NSRP

National Shipbuilding Research Program

Development of a Shipbuilding Simulation Process Modeling Database (4-98-3)

June 30, 2000

Final Report

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Executive Summary

The overall objective of this NSRP project has been to develop a library of process modeling components to be used for discrete event simulation of shipbuilding operations. The project has focused on the operations involved with initial plate processing. These processes were found to be similar among different shipyards, making the results of this work applicable to a broad audience. The library of process model components has been incorporated into an interactive web site. This provides a means of access to process simulation to people who may not be knowledgeable in the methods or tools of modeling and simulation. The process model library and web site are a step toward enabling the exchange of process simulation models and collaboration between shipyards on process modeling efforts.

The use of software tools for discrete event simulation is a powerful means of evaluating processes and operations. These tools provide statistical output that can be used to determine bottlenecks and resource limitations in existing and proposed workflows. This is especially important in shipbuilding and other heavy industries where changes in workflow and automated equipment represent a large capital investment. Discrete event simulation can be used to verify the usefulness and return on investment of process improvements. The ability to do accurate capacity and throughput planning is also valuable for US shipyards, which face ever changing work orders and demand. The use of simulation tools for capacity forecasting helps support cost effective limited production operations.

This project has developed a library of reconfigurable process model components. The operations that were selected for modeling were the initial steps in plate processing. A study of a number of shipyards showed that these operations were similar between different shipyards. The machines and operations in initial plate processing were modeled using discrete event simulation software. Each machine and operation were created as separate, component models. The controlling values for these models were left to be user defined input variables. Supporting programming was done in the simulation software to allow these components to be combined in a variety of layouts. The resulting library of process components can be used to create larger composite simulation models “on the fly.”

The library of process model components has been made accessible through an interactive web site. The web site enables a simulation model to be built and executed through the use of a simplified interface. Simulation results are stored on the site during execution and can be viewed by the user after email notification has been sent. This design provides easy access to discrete event simulation capabilities for those who do not have the training or resources to use simulation. The reconfigurable process model library, which serves as the simulation engine for this web site, enables different models to be built rapidly. This gives the user a practical means of doing quick capacity planning or trade off studies for potential process line layouts.

The process model library and the interactive web site are a step toward the open exchange of process simulation models. The exchange of process models and simulation data between different software packages and organizations is an unsolved problem. The ability to exchange process models would foster the increased use of simulation by encouraging reuse and refinement of existing models and by enabling collaboration in modeling between different organizations. This would be especially helpful to smaller shipyards that cannot support the investment or resources to engage in simulation on their own. The ability to collaborate on process simulation work would also be in line with the emerging business model in the shipbuilding industry of teaming and joint projects.

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1. Introduction

The overall objective of this NSRP project has been to develop a library of process modeling components to be used for discrete event simulation of shipbuilding operations. The project has focused on the operations involved with initial plate processing. These processes were found to be similar among different shipyards, making the results of this work applicable to a broad audience. The library of process model components has been incorporated into an interactive web site. This provides a means of access to process simulation to people who may not be knowledgeable in the methods or tools of modeling and simulation. The process model library and web site are a step toward enabling the exchange of process simulation models and collaboration between shipyards on process modeling efforts.

This NSRP project has been a joint effort between Electric Boat Corporation and the Applied Research Laboratory at The Pennsylvania State University. Work on this project was conducted over a fourteen month period from May 1999 through June 2000. The project was broken down into a number of separate tasks. These included evaluation of discrete event simulation software, documentation of shipyard manufacturing processes, development of process simulation models for shipyard processes, and the development of a web site for interactive use of these simulation models. Work was also done in the area of exchanging process models between different simulation software packages.

This document is the final report for this NSRP project. The body of the report contains detailed descriptions of all the work accomplished under this project and the results of this effort. This is followed by a discussion of the conclusions reached, and recommendations for additional work. Additional tabular and graphical information supporting the text is contained in four appendices. Part of the work done under this project was the creation of an interactive web site. The results of this effort cannot be accurately represented in the format of a text report. The reader is advised to review the web site directly at the URL <http://dice.arl.psu.edu>.

2. Assess Simulation Software Packages

2.1 Overview

The first task of this project was to assess commercially available discrete event simulation software packages and select the best one for the project. This section is a summary of this selection effort.

Process visualization was an important part of this project. Realistic three-dimensional visualization of plate processing, and of manufacturing processes in general, is a critical factor of evaluating whether a new technology is feasible in a shipyard. A visual presentation is an excellent way to introduce new technology and processes. It allows designers, workers, and management to have a realistic view of the new technology prior to implementation. This can be very important in influencing management to fund process changes and related capital improvements. Shipyard workers can provide feedback without having to understand complex statistical data, reports, or graphs. It will also aid in the culture change involved when transitioning from present to future processes; workers can visualize how jobs would change.

Two other import issues were interactive input/output of data and the ability to combine multiple models together into a larger model. It was envisioned that models would be created and simulations run from data input from a remote site through the World Wide Web. Results data in visual (direct display, video, animation files), graphical and textual form would be output to the remote user. The intent was to build individual component models and to join them together on the fly to create larger models. These features would need to be supported by the simulation software.

There are many different types of simulation software available. Information on simulation software was obtained from The Simulation Education Home Page (<http://www.pitt.edu/~wjyst/nsfteachsim.html>), the Winter Simulation Conference Proceedings web site, general simulation sites, and software manufacturers' web sites. The 1999 Operations Research and Management Sciences *Today* Simulation Survey and The Institute of Industrial Engineers *Solutions*, May 1999, Simulation Software Buyer's Guide list many software packages and their attributes.

Several discrete event simulation software packages that are manufacturing oriented were selected for assessment. Demo/evaluation copies of Arena, AutoMod, ProModel, Quest, Taylor II and Witness were obtained. The simulation software was evaluated for ease of use, input/output of data, and visualization characteristics. After the initial assessment of the simulation software packages, the project team decided to focus the evaluation on AutoMod, ProModel and QUEST because these best met the evaluation criteria. A matrix was created to compare the software packages (see Table 1).

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	AutoMod	ProModel	QUEST
Software License	\$15,000	\$16,900 (includes optimization suite and training)	\$15,000
Operating System	Windows 95, NT	Windows 3.x, 95, NT	Windows 95, NT, UNIX
Run-time version	Yes	Yes	No
Add-ons	<p>Simulator- template for capacity planning</p> <p>AutoView- post process animation package</p> <p>AutoStat- enhanced analysis during experimentation</p> <p>Model Communication- send/receive data between models and third party applications</p>	<p>Optimization suite:</p> <p>SimRunner- allows automatic “what if” scenarios to be run</p> <p>Stat::Fit- distribution fitting software</p>	<p>NOTE: The following are included with QUEST:</p> <p>Batch Control Language (BCL)- batches simulation runs automatically for optimization</p> <p>Simulation Control Language (SCL)- used to define custom behavior, distributions</p>
Software Type	Manufacturing-oriented Simulation Language	Manufacturing-oriented Simulator	Manufacturing-oriented Simulation Language
Model Building Capabilities	Graphical, Programming, Run-time Debug, Output analysis, Code reuse	Graphical, Programming, Input distribution fitting, Run-time debug, Output analysis, Code reuse	Graphical, Programming, Input distribution fitting, Run-time debug, Output analysis, Code reuse, Run multiple models
Animation	True 3D Graphics, Real-time animation, CAD-like drawing utility, Import IGES format	2D Graphics, CAD drawings as clipart, Graphics Editor has complete set of drawing tools, 3D perspective layouts, CAD layout drawings for model background	True 3D Graphics and Real-time animation, Integral CAD package, Import from IGES, DXF, CATIA, Pro/E, Unigraphics, other Deneb products. IGRIP models and cycle times can be directly imported. Compatible with VRML 2.0
Inputs/Outputs	Data input through tables, Reports, Tabular and Graphical outputs, AVI output using AutoView	Interactive input and output of data, Read/export data from external text or spreadsheet files. Textual reports and Graphical outputs, uses MS Visual Basic and ActiveX for external model creation and execution	Interactive input and output of data, Read/export data from external text or spreadsheet files, MS Project, Excel, Access, and Visual Basic. Import simulation models from Deneb products, ASCII files and Graphical outputs, 3D or 2D CAD Geometry files, AVI, MPEG movie output. Synchronous communication, SYSLINK, RADEO, CNRC

Table 1. Software Evaluation Matrix

2.3 Comparison

2.3.1 AutoMod

AutoMod by AutoSimulations is a manufacturing oriented simulation language that uses 3D animation and a graphical interface to aid the user in modeling, analyzing, and visualizing complex manufacturing processes. AutoMod runs on Windows 95 and NT platforms. It uses a CAD like interface to define physical elements of a system. Logic is entered using parametric tables or AutoMod's 4GL language. It has predefined material handling modules that simplify modeling (automatic guided vehicles (AGVs), conveyor, power & free, bridge cranes, automated storage and retrieval systems (ASRS), and kinematics). After the user has defined the physical and logical components of the model, it is compiled into an executable model, where the simulation and animation run concurrently. The executable allows the simulation to run very fast and with animation on or off. Model outputs include the 3D animation, customizable reports and graphs. It has several add-on modules that help in model creation and outputs.

2.3.2 ProModel

ProModel by ProModel Corporation is manufacturing oriented simulator that is Windows based. It has a very easy to use graphic interface that allows creation of models using the point and click approach. All input is graphical, grouped by object type, and in spreadsheet-like format. Dragging and dropping objects from menus and filling in the inputs to text fields easily creates models. It has an integrated help system that uses the Windows Help system that makes this product easier to use for anyone familiar with Windows products. Complex logic can be coded in programming languages such as C, Pascal, or Basic and may be dynamically linked to the model. There is an extensive library of 2D Graphics and the ability to create and add to the library by importing or using the graphics editor. 3D layouts may be created. Animation is in 2D and in real time. Models may be run with or without animation. Outputs include the real time 2D animation, customizable, exportable reports and graphs. Included in the Optimization Suite is an optimizer and distribution fitting software.

2.3.3 QUEST

QUEST by Deneb Robotics Inc. is a true 3D discrete event manufacturing oriented simulation package with a graphical interface that facilitates model creation using graphics libraries in 2D or 3D. The software will run on Windows 95, NT, and UNIX operating environments. It can also import, export and internally create 2D or 3D geometry. Material flow logic is grouped in modules for conveyors, labor, AGVs, kinematics, power and free, and automated storage and retrieval systems. It has a simulation programming language for additional capabilities, such as external model creation and control, multiple runs for alternate scenarios (what-ifs), and exceptions to standard routing and scheduling selections. Onscreen messaging aids model development and Help files are hypertext documents accessed through the Netscape

browser that is provided. Models are run using 3D real time graphics, with standard and customizable reports and graphs, video, and AVI, JPEG, MPEG, and Tiff outputs.

2.4 Summary

All the software packages that were evaluated were capable discrete event simulation tools. The deciding factor was visualization and the ability to generate and execute models externally. QUEST was chosen due to its powerful visualization features and its external model creation capabilities. It is a 3D graphics based simulation package that specializes in manufacturing systems. It has a graphical user interface along with a powerful programming language for additional capabilities. It imports and exports 3D and 2D CAD geometry from a variety of CAD formats and custom geometry can be created using the internal CAD tool. QUEST's 3D animation allows the user to fly around or zoom in on the model and examine performance statistics in real time while the simulation is running. This realistic 3D simulation provides a very effective means of communicating the behavior of a manufacturing process.

QUEST also imports and exports data to and from external systems, enabling direct communication with spreadsheets, project planners, ERP and MRP systems. QUEST allows automatic generation of simulation models from external data using Microsoft Visual Basic and Excel spreadsheets and provides a Virtual Collaborative Engineering (VCE) environment where individuals can remotely view and interact with the same model simultaneously at remote sites using TCP/IP socket connections. Statistical results can be viewed with graphical and numerical analysis capabilities. Model graphics and animation can be output in several formats.

3. Document Shipyard Manufacturing Processes

3.1 Overview

The second task of this project was to identify and describe the manufacturing processes and equipment determined to be common to shipyard manufacturing operations. These common processes would then be modeled using the QUEST discrete event simulation software. In order to gather process information, site visits were made to a number of shipyards in the Northeastern United States to observe their manufacturing processes. These included Electric Boat's Quonset Point facility, Bath Iron Works, Pequot River Shipworks, and Southeastern New England Shipbuilding Corporation (SENESCO). Additional process information was also gathered for other shipyards from previous visits and published reports.

In all of the shipbuilding process information that was gathered there is a large degree of similarity between the various shipyards. There are also some specific differences and unique aspects of each shipyard based on factors such as materials used, customer specifications, and historical physical plant layout. There is enough similarity in the shipbuilding process to begin to put together a general model of the overall process. Some of the common tasks observed in the early stages of ship construction include material treatment, plate processing, shape (profile) processing, bending and forming, kitting, panel line and general subassembly, and block assembly.

This NSRP project concentrated on the initial steel processing operations of material treatment and plate and shape processing. This narrow focus allowed the modeling effort to be undertaken in greater detail. Plate processing was also the most generic and commonly practiced step in the overall shipbuilding process. Using this narrow focus would allow the data sharing aspects of this project to be applicable to the broader shipbuilding community.

This section provides detailed descriptions of the operations involved in material treatment and plate and shape processing. This is followed by descriptions of plate and shape processing at the specific shipyards visited during the project. The equipment and process steps used to perform these operations and the detailed parameters required for modeling these processes are listed in Appendix A. This information was used to build detailed simulation models for each machine and operation.

3.2 Steel Processing

3.2.1 Material Treatment

Typical treatment methods are used to prepare shapes and plate for processing. Depending on the shipyard they will remove paint or mill scale by blasting, and add primer. The typical process is to have plates and shapes loaded onto an input conveyor by forklift, crane, and/or transfer car. On the conveyor the material will pass through a drying oven, a blast machine and automated paint sprayer and dryer. Completed shape

material will then be transferred to shape processing and plates to plate processing by conveyor, transfer car, crane, and/or forklift.

Processing time for material treatment is a function of drying time, blast rate, paint rate, and dry time. This time will vary based upon what equipment a shipyard uses and the specific operational sequence followed. Some shipyards do not use a drying oven before the blast machine. Some yards apply primer paint immediately after blasting, while others work with clean plate.

3.2.2 Plate Processing

Plate processing consists of cutting detail parts from a raw plate. One piece or many pieces may be cut from a single piece of raw plate. Plate is placed on a cutting table (water or downdraft) where it is cut using a CNC burning machine. Processing times are dependant on setup time, marking time, type of cutting head (i.e. plasma, oxy-fuel, laser, water jet), number of cutting heads on a gantry, plate thickness, length of cut, type of cut (straight, bevel, double bevel), number of pieces in a nest, and removal of parts. Parts needing additional processing (beveling, part cleanup) are sent to a manual operation area, while finished parts are sent to kitting.

Overhead gantry cranes are used to load/unload the tables and transport parts to kitting areas. Most cranes are unable to remove small parts and scrap. They are generally manually removed and placed on pallets. Forklifts transport small parts. Material handling times are based on loading and unloading times, the operational speeds of the crane and forklift, and the distance they have to travel.

Piece parts are typically marked with part number, lot number, and other information either before or after cutting. Marking may be accomplished by the burning machines (many CNC burning machines have the ability to perform pin-stamp and/or ink marking) or may be done as a separate process step. The time for marking is a function of type of marking used, how much information will be marked on each part, and number of parts to be marked.

3.2.3 Shape Processing

Shape processing consists of cutting detail parts from lengths of raw shape stock such as I-beam, angle iron, flat bar, or square stock. It is typical for many parts to be cut from a single piece of stock. Material is brought in using conveyor, forklift, transfer car and/or overhead crane onto roller tables, where layout for cutting is performed. The work is then fed either to band saws, ironworkers, or burners. Marking is performed during the layout operation and/or after the piece has been cut. Cut parts are removed by overhead crane, forklift, or manually depending on part size and moved to a kitting area or secondary operations. Secondary operations include beveling, notching, and hole punching.

Processing time is a function of material transport (operational speeds of transporter, distances traveled), equipment cutting times (cut rate - cutting speed based on thickness, length of cut), number of pieces in a nest, marking time (type of marking, amount), secondary operation times, and kitting time.

3.3 Bath Iron Works

Bath Iron Works (BIW), a General Dynamics Company, was established in the 1840's and is located in Bath, Maine, with facilities in Brunswick and Portland, Maine. BIW is a designer and builder of technologically advanced naval surface combatants. They are currently the lead on the DDG 51 ARLIEGH BURKE Class AEGIS guided missile destroyer, and are preparing for construction of the new class of amphibious assault ships, the LPD 17. The shipyard is currently modernizing and expanding its facilities with a new panel line, blast-paint building, a Land Level Facility for assembly and erection, and a new floating dry-dock.

Material processing is accomplished at the shipyard's Harding facility in East Brunswick. Plate is received by rail truck and offloaded to a plate storage yard by the storage yard bridge crane. When plate is needed for fabrication the bridge crane retrieves plates from the yard and places them onto the three "P" stacks near the input conveyor. Shape material is retrieved using a mobile crane, forklift and/or straddle lift. The plate yard has several crews consisting of riggers, crane operators and material handlers working simultaneously. A travel lift with a magnetic head places the material onto the input conveyor. Material on the conveyor passes through a drying oven, blast machine, and paint and dry machine and then to the output conveyor. Material moves to a transfer car that travels to the entrance to the burning area, where it is moved to another transfer car. The second, manually operated transfer car unloads plate material onto the floor of the burning area at the location of the machine on which it will be processed. Shape material passes through the plate burning area by transfer car to an offload conveyor, which unloads the shape material into bins.

3.3.1 Plate Processing

The burning area has four CNC cutting systems parallel to each other. Plates are picked up off the floor in the burning area and delivered by bridge crane to one of the four machines based upon the pile it was in. The plates are loaded onto the cutting tables by a crane operator. Each machine has one operator. One machine is dedicated to gang cutting of common parts. All cutting systems have the capability to perform Zinc powder marking except the machine for common parts. Almost all parts and scrap are removed from the cutting tables using the two offload bridge cranes. Each crane has a crane operator/material handler. Parts that cannot be removed by crane are removed by hand. Most parts are marked after cutting during removal process. Parts are hand marked using paint marker and bar code. Cut parts are transferred from the area using the bridge cranes and/or transfer cars either to secondary operations, subassembly, or a finished parts area.

The machine used for cutting common parts has seven oxy-fuel cutting heads with a dry table with a slat conveyor. After cutting, the conveyor moves parts to the end of the table, where they are removed directly into bins or offloaded by crane or by hand and labeled. Scrap is put into scrap bins.

The second cutting machine has two large downdraft tables. It has one dry plasma cutting and beveling head and its own part-handling gantry. Parts are labeled by the operator after cutting before unloading. Parts and scrap are removed using the gantry and one of the two offload cranes.

The third cutting machine has a watertable with a slat conveyor and submerged cutting head. After cutting, parts and scrap are moved to the end of the table by the conveyor, and removed and labeled by the operator.

The fourth cutting system has six watertables on a roller system that can place two tables under the cutting gantry at a time. The gantry has two submerged cutting heads that can cut mirror images on two plates simultaneously. The tables are moved out from under the cutting gantry to load plate and unload cut parts.

3.3.2 Shape Processing

Shape Material in bins is delivered by crane to the shape processing area. Flat bar and angle iron go to two ironworkers, tubing material goes to two Marvel vertical bandsaws, and all other shape material goes to eight manual down-draft burning tables, where material is cut with handheld plasma cutters. Material layout and marking is done manually before cutting, and after cutting bar codes stickers are applied. Cut parts are offloaded manually by the fabricator or by crane and placed onto pallets or bolsters. The pallets are delivered by forklift, and bolsters are delivered by a straddle lift to either the finished parts area or subassembly areas.

3.4 Pequot River Shipworks

Pequot River Shipworks, established in 1996, is located in a former steel fabrication facility in New London, Connecticut. There is enough room in its 60,000+ square foot, fully enclosed production facility to build three vessels at the same time. The shipyard's main business is the construction of International Maritime Organization (IMO), Det Norske Veritas (DNV), and United States Coast Guard compliant High Speed Aluminum Ferries designed by FBM Marine Group of the Isle of Wight, United Kingdom. The facility is also capable of manufacturing shallow draft vessels and other products fabricated from aluminum or steel. The shipyard receives unpainted DNV certified marine grade aluminum that is ready for use and does not have a need for a blast-paint facility at this time. Material is delivered by truck.

3.4.1 Plate Processing

The 7' by 20' plates are offloaded by forklift and overhead gantry crane to the plate storage area. Plates are transported by overhead gantry crane to an 8' by 40' downdraft table. The operator loads the nesting program into the CNC plasma cutting system from disk or from a standard program stored in the machine. After cutting, the parts are hand marked with ink as they are removed from the table. They are marked with part number, lot number, and material type. Large cut parts are removed by crane to the part storage area or delivered to the fabrication area using a forklift. Small cut parts are removed manually and placed in storage bins. Small remnants are stored next to the cutting machine and large remnants are returned to the plate storage area. Scrap is placed into a bin next to the cutting machine. The cutting machine operator performs all the tasks in the plate processing operation.

3.4.2 Shape processing

Delivered shape stock is unloaded by forklift and stored in the shape storage area. Welders/fabricators pull stock as needed out of storage and cut pieces to the required length using an Ironworker for flat stock, and cut-off saws or a bandsaw for profiles. After cutting, parts are labeled and taken to the assembly area by the fabricator. Remnants are placed on a remnant rack and scrap is put into a scrap bucket.

3.5 SENESCO

SENESCO (Southeastern New England Shipbuilding Corporation) was established in 1994. The facility is located at Quonset Point, Rhode Island, on a 25-acre site with two former aircraft hangers. These hangers were formerly used by Electric Boat and were upgraded for submarine construction. The buildings have a total of 260,000 square feet of manufacturing space that is serviced by 11 overhead bridge cranes. Nine of these cranes are of 15-ton capacity. After receiving expansion financing in 1999, SENESCO has started installing new equipment. An Ogden Panel Line, a Versagraph dual head CNC thermal cutting machine and many new welding machines, including automatic welders, have been installed. Six people operate the panel line, which is capable of constructing stiffened panels up to 40' by 40'. The shipyard has future plans to install marking equipment on the cutting machine. A 20-foot Pacific CNC brake press will be installed in December 1999. The shipyard plans to install a tandem brake press to achieve 40-foot bending and forming capacity.

The shipyard is focused on building barges for all types of use, with plans to expand operations to include all types of tug boats, shallow draft vessels and freight railroad cars in its all-new facility. The shipyard has just recently started construction on its first contract, a 140-foot construction barge to be used as a platform for cranes. The shipyard currently purchases material precoated to contract specifications and has future plans to install a blast and paint facility.

3.5.1 Plate processing

Plate is received by rail or truck and delivered by truck to the fabrication and subassembly hall and stored near the panel line and the cutting machine where it can be easily loaded onto a watertable by overhead crane. The table can hold two 10' by 40' plates. The cutting technician operates the dual head CNC cutting machine. After cutting, all parts are hand marked and removed by the overhead crane using magnets to a roller-conveyor. Stiffeners for the panel line are removed by overhead crane and placed in a cassette. The cassette is transported by overhead crane and placed onto the panel line. Other parts are sent to either the panel line or to the subassembly area. The operator unloads small parts and scrap that cannot be unloaded by the crane. Scrap is placed in scrap bin and remnants are stored near the cutting machine. One technician performs all tasks in the plate processing operation while other personnel may aid in material transfer.

3.5.2 Shape Processing

Shape Material up to 40' long is delivered to the shape processing area of the fabrication and subassembly hall. Delivery trucks are offloaded by forklift or crane and placed onto manual roller tables that feed the vertical bandsaw and ironworker. The machine operator hand marks the raw stock and then cuts detail parts. Parts are fed to an output roller table and removed by the operator manually or by overhead crane. Small parts are palletized. Parts are then sent to the subassembly area. Parts for the panel line are loaded into a cassette from the cutoff saw. One technician performs all tasks in the shape processing operation while other personnel may aid in material transfer.

3.6 Electric Boat Corporation

Electric Boat Corporation (EB), a General Dynamics Company, was established in 1899 and has manufacturing facilities in Groton, Connecticut, and Quonset Point, Rhode Island. EB is the world's leading designer and builder of submarines and is currently teamed with Newport New Shipbuilding in the construction of the next generation of submarines, the VIRGINIA Class. Electric Boat does not weld painted material or use weldable primer. Therefore, material is not blasted or painted before performing plate and shape processing. Parts are blasted after kitting and painted after subassembly.

3.6.1 Plate Processing

When plates are requested, the plate yard workers use a forklift or straddle crane to retrieve the material from the plate yard. Plate is delivered outside the door of the plate processing center. One processing land consists of a railcar that the plate is placed on and brought into the building, where it loaded onto a marking table using a TTS gantry crane. A marking gantry performs marking on one side of plate. After marking, the plate is transferred by TTS gantry crane to a DNC plasma cutting machine with a watertable. This machine is mainly used for cutting ferrous material and is capable of cutting plate up to 8 ½' by 30'. The work is performed by two operators, one for each machine, or by a single operator at a slower pace. The operator and a helper unload the cutting machine

using an overhead bridge crane or the TTS gantry crane depending on part sizes. Small parts that cannot be unloaded with the cranes are unloaded manually.

The processing center has a second DNC plasma cutting system with a watertable. It is capable of cutting plates up to 11' by 64'. This machine is used for cutting nonferrous (4' by 8') and ferrous plate. Material is loaded using an overhead bridge crane and unloaded using the crane or manually by the operator and a helper.

Cut parts are marked and laid out, and then sent to the finished parts or secondary operations areas. Small parts are palletized for transportation. Remnants are inspected for markings and sent back to the plate yard, while fractional plates are stowed inside the building. Scrap is placed in scrap bins.

3.6.2 Shape Processing

Shape material is requested from the plate yard by nested length. The plate yard workers will cut material to length using an oxy-fuel hand torch cutter if proper length is not available. The material is transported by forklift to the door of the processing building. The material is brought into the building using a forklift. All shape material typically goes to a vertical bandsaw for cutting, but can also go to an ironworker (flat bar and angle iron) or to hand burners if needed. The operator cuts, marks, and performs layout operations. Finished parts are palletized and delivered by pallet mover or forklift to the stowage area, and then on to kitting. Unfinished pieces are sent on to secondary operations within the processing center. They are moved manually, by pallet mover, or forklift. Scrap is placed in scrap bins.

3.7 Process Parameters

The tables in Appendix A list the process steps, equipment, and controlling factors that define the initial stages of the common shipbuilding manufacturing process. The process logic and quantitative values of these controlling factors were used to build the simulation model components for the library developed in this project.

4. Develop Simulation Models

4.1 Overview

In the third task of this project models of shipyard manufacturing operations were developed using the QUEST discrete event simulation software. These models were based on the common processes and equipment used in shipyard manufacturing operations identified previously. The operations selected for modeling were initial material treatment and plate cutting and marking. Plate processing was a generic step in the overall shipbuilding process, making the results of this modeling effort useful to a broad community.

4.2 Simulation Models

Simulation models were developed for the initial steps involved in plate processing. These steps consist of Pre-drying, Blasting, Priming, Cutting, and Marking. Generic process models were developed for these operations using the QUEST discrete event simulation software from Deneb Robotics. Each operation was modeled as an individual component. The models are reconfigurable based on user supplied input. This allows the user to specify values that are appropriate for a particular machine or shipyard procedure. Descriptions and illustrations of each of the process model components are provided in Appendix B.

The intent of using reconfigurable component models is to quickly tie multiple models together to produce a larger simulation. By providing a library of generic components a user can select between a large number of potential variations to match the desired configuration. Specific values for each process step, such as feed rates and input scheduling, are provided by the user to represent the actual machines and operations used at a particular shipyard. A composite model using the selected components is then built “on the fly.” User input and control of the component joining process is managed through a text file and the use of BCL (Batch Control Language) and SCL (Simulation Control Language) programming languages in QUEST. In future tasks of this project, user input and model configuration will be controlled through a web browser interface.

The image in Figure 4-1 illustrates some of the components of the process model library that has been developed. Individual models have been tied together to form a plate processing line containing blasting, priming, marking, and cutting stations. This process line represents only one specific configuration of components. All of the available components have been incorporated. Many variations could be generated based on the needs of the user. The actual QUEST model files that correspond to the process shown in Figure 1 are included electronically with this report in Appendix B. An animated sequence showing the flow of parts through this process line is included as a movie file (AVI) in Appendix B.

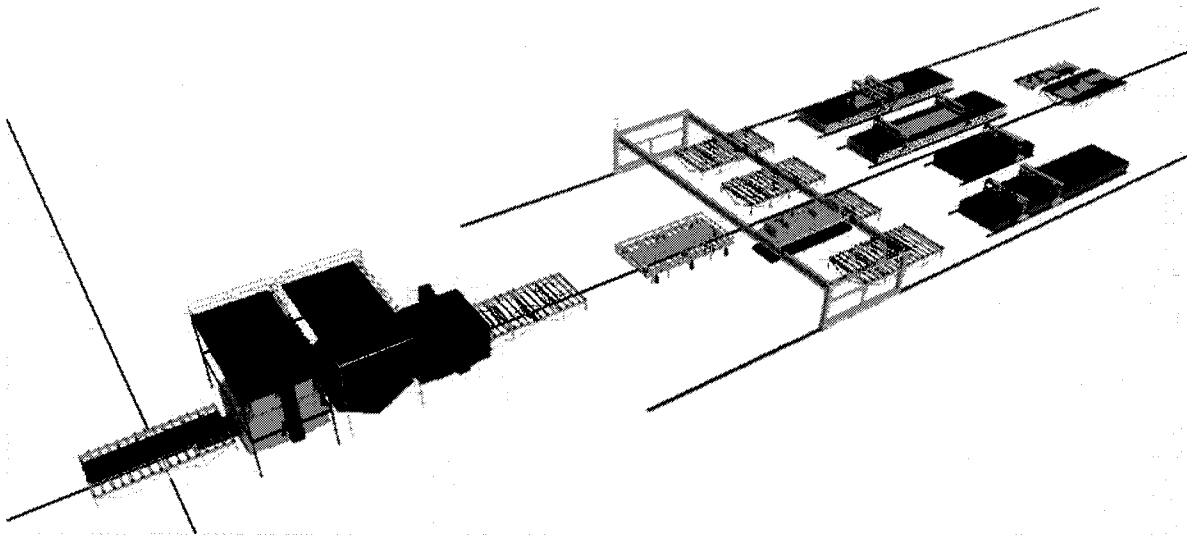


Figure 4-1. Initial Plate Processing

In order to support the creation of component models, extensive process modeling work was done under this task using QUEST. Detailed, large-scale models were developed in conjunction with evaluation of new facilities at Electric Boat's Quonset Point site and capital improvements at Bath Iron Works. These were built as large, monolithic models using traditional discrete event modeling techniques. Portions of these large-scale models were used as the basis for the individual component models in the library delivered under this task. The component model library was based on the detailed process information collected under the Document Shipyard Processes task of this project.

5. Develop Web Site with Simulation Model Database

5.1 Overview

The library of process model components developed under this project was made accessible for use through an interactive web site. The web site enabled a user to select desired process components from the library and assemble them into a simulation model. Specific values for various process parameters (i.e. cut part quantities, machine speeds, etc.) and an input schedule were also provided by the user. The simulation model was then submitted to run in the background at the web site. When the simulation was complete the user was notified via email and was sent a URL pointing to the results. The results available for each simulation run included text-based statistical output and a movie of the 3D scene running.

5.2 System Design

In order to provide users access to the simulation models via a web interface, a distributed computing environment was created. The computing environment used for this project was based on a system developed at ARL Penn State named DICE (Distributed Intensive Computing Environment). A system diagram of the distributed environment is shown in Figure 5-1.

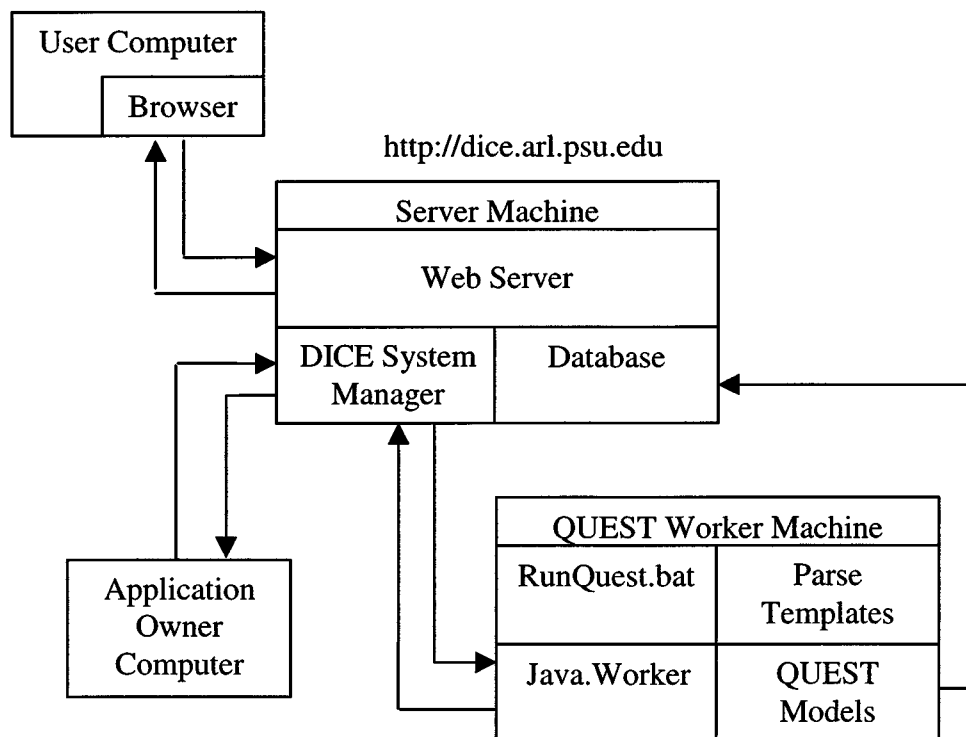


Figure 5-1. DICE System Configured to Run Quest Models

The DICE system enables a remote user to access the library of simulation models in a controlled manner. Users must be granted a password before they can access the system for the first time. Permission to use a specific DICE application must be granted by the owner of that application. In the case of the process model library and the QUEST simulation software, this NSRP project is the owner. The overall DICE system contains many different applications and has many different users. Users only have access to their own data, and cannot “see” other users of the system or their data.

The system is operated as follows:

1. The remote user connects to the DICE web server (<http://dice.arl.psu.edu>).
2. Upon connecting the first time, a user will select a module from the available list of applications on the DICE Server (Quest in this case) and request access. The DICE System Manager will email the owner of this application, who will grant the new user access to a set number of simulation runs.
3. Once approved, a user can request to run an application.
4. To run the Quest application, two tasks are required:
 - a) First, the user must either have an existing schedule file resident on their local computer, or create a new schedule file. The schedule file is a text file that contains information about the number of plates to be cut, their material, length, thickness, number of pieces per plate, inches of marking on the plate, and the day-based start time for each individual plate. If the user wishes to create a sample schedule file, an Excel macro can be downloaded that will prompt the user to create the file.
 - b) Next, the user needs to configure the plate processing layout desired. This entails selecting the desired machines (blast, dry, prime, mark, cut) and setting some basic characteristics about the machines (i.e. speed, type of cutter, etc.). The result of this is a set of key value pairs that defines the parameters of the simulation model.
5. Once the configuration is defined, the user uploads a schedule file and submits the job to the DICE System Manager.
6. The DICE System Manager provides the schedule file and the set of key value pairs from the web interface to the simulation processor. The sub-module RunQuest.bat starts, and the ParseTemplates sub-module generates a BCL (Batch Control Language) file. The BCL file defines the simulation model that is subsequently run in the QUEST environment. Upon completing the simulation run, the resultant files (text for run statistics and a series of JPEG files for visualization of the simulation)

are stored in the DICE database under a subdirectory of the type
\\dir\\Quest\\username\\runid.

7. When the run is complete, the DICE System Manager notifies the user via email that the run is complete. The user then re-enters the web site to retrieve the results of the simulation from the Server Machine.

A package of on-line instructions has been developed for the use of the process modeling library web site. These instructions are presented in Appendix D. Additional detailed information about the design, architecture, and use of the DICE system to run Quest simulation models is included in Appendix E.

5.3 Summary

The interactive web site developed under this task provides a simple means of access to process modeling and simulation for shipbuilding. The user is not required to have any detailed knowledge of process modeling or of discrete event simulation software to make use of this site. This enables shipyards to take advantage of simulation without having to make an investment in trained staff resources or software. The web site enables users to build plate processing line models quickly, using the process model component library. The user can easily assemble different configurations and modify controlling parameters through a simple browser interface. The web site provides an effective means of doing quick capacity planning or trade off studies for potential plate processing layouts.

The use of an interactive web site and process model library has limitations for large or detailed simulation projects. The current process model library contains components dealing with the initial steps in plate processing. These steps are relatively simple to model compared to the subsequent, more complex operations of kitting, sub-assembly and assembly fabrication, and block erection. Considerable effort would be required to model these downstream operations as reconfigurable components. The web site offers little control over the 3D layout of the models created, or routing logic. Adding 3D layout controls or sophisticated routing capabilities to the web site would greatly increase the complexity of the system. For simple capacity experiments or machine selection the web site offers an effective tool. For more detailed simulation efforts it will be necessary to make direct use of discrete event simulation software tools.

6. Exchange of Discrete Event Simulation Models and Data

6.1 Overview

The exchange of simulation models between different discrete event programs was one of the overall goals of this NSRP project. Effort was spent during the modeling task to study the feasibility of exchanging process model data. The process modeling work done under this project, at both Quonset Point and Bath Iron Works, had a practical need for such model exchange. Some modeling work was being done concurrently at these sites using the ProModel simulation software from ProModel Corporation. The ability to exchange process model data would have allowed the models developed in ProModel to be incorporated into the large-scale QUEST models without duplication of effort.

In order to efficiently and successfully exchange process models between discrete event simulation programs either a two-way translator/converter needs to be developed or the models need to be stored in an agreed upon neutral format file. No direct translators currently exist for the conversion of models between QUEST and ProModel. Translator development is not trivial. The development of a translator requires a broad understanding of discrete event simulation and in-depth knowledge of the sending and receiving systems. The following factors must be considered in relation to discrete event models.

- Geometric Representation
- Component Arrangement
- Component-to-Component Connectivity
- Component Behavioral Logic
- Order/Job Creation and Scheduling
- Output Requirements
- Interactive Simulation Control

The specification of a common neutral format for exchanging process models is also a very large task. Work on this effort, the Process Specification Language (PSL), is ongoing under direction of the National Institute of Standards and Technology (NIST). The initial focus of PSL is to create a broad catalogue (ontology) of the types of data required to describe processes. The PSL project will then work on prototyping the translation of models between specific simulation programs. For additional information on PSL see <http://www.mel.nist.gov/psl/>. A description of how PSL would be used to convert discrete event models from one simulation program is available at <http://www.mel.nist.gov/psl/p4/exchange/index.html>

6.2 Exchange of Process Models

For the purpose of this task a manual, or “brute force,” translation method was employed. The goal was to transfer a process simulation created in ProModel to QUEST. In the worst case this amounts to a re-creation of the model from scratch in the destination software tool. This re-creation is a time consuming and error-prone method of obtaining

results. In the best case, portions of model layout, process logic, and schedule data can be extracted from the source model and used “as is” in the destination model. The experience of this task fell closer to the former, re-creation end of the spectrum. Final conversion of the ProModel models into QUEST was not fully accomplished.

The translation work done under this task dealt with only two specific discrete event simulation tools, ProModel and QUEST. Based on extensive data exchange experience, it is believed that the results of this translation exercise are representative of process model exchange in general. Some of the lessons learned from this conversion/translation exercise are given below.

The geometric representation used by two process modeling tools may be different. Some tools use a notional 2-Dimensional layout for machines and parts, while others depict objects by icons without any true spatial relationship. An extreme example would be model transfers between a 2-Dimensional and a 3-Dimensional simulation. 3-D geometry could be represented as 2-D screen shots or substituted by icons, but there is no automatic way to convert a 2-D representation into the third dimension. Often there is some 3-D geometry available for machines and facilities because they have been modeled in a 3-D CAD system for other purposes. The 3-D geometry may still need to be translated into the format of the “destination” discrete event modeler. This is typically straightforward since most 3-D modeling systems can interact with industry standard file formats such as IGES, DXF, VRML, and SLA. If no appropriate geometry can be located, a user would have to generate the desired geometry or use default block forms.

Other geometry related issues are the relative positioning of machines and the display of created or modified parts. If a modeling tool uses the graphical layout to specify the distances between operations and connectivity, then this will affect transport time and routing logic. For tools where the graphical layout is not significant, connectivity and transport will have to be captured in the definitions of the operations rather than inferred from the layout. The location and presentation of this data will need to be accounted for in exchanging models between different tools. Modified or created parts (joined or cut) may also need to be represented with specific geometry or images. This information may either be superfluous or not available, depending on the nature of the source and destination models.

Each step or operation in a discrete event model has a process logic that is used to determine the amount of time and resources required to perform the operation. The values are typically based on a random solution to some distribution function, and may include factors for machine breakdowns, labor rules, and shift times. Individual steps are also tied together by routine, conveyance, and buffering logic. All of this process logic comprises a description of the simulation. In order to convert a simulation from one modeling tool to another, this process logic needs to be extracted and reinserted. This is not a straightforward task. Some tools allow process logic to be created through the use of external interfaces such as Visual Basic or Excel spreadsheets. However, in most tools there is no simple way to extract the required values from a model and there is no standard format to document these values. At this point the translation process breaks

down to manual reentry of data. Although it is difficult to transfer this data, most discrete event simulation tools make use of similar constructs for this process information. Once the data is available it can be readily inserted into the destination model.

Process simulations are usually driven by input values from either a schedule of start times or the availability of raw materials. This information is typically provided as input from outside of the simulation program by way of text files or spreadsheet data. This type of data is easier to transfer between modeling tools because it is external to either tool and can be transferred in its native format.

Differences may also exist between modeling tools in how the user interacts with the simulation process. This includes user control over starting, running, and modifying simulations and the display of output values. Some tools allow the use of a customized “front end” through Visual Basic or some other dialog language. Other tools only allow direct manipulation of the supplied user interface. Output can take the form of tabular files, graphs, charts, or screen animations. External post-processing may be required for some tools to generate the desired format of output results.

6.3 Summary

The transfer of discrete event simulation data from one modeling tool to another is a difficult process. There is no standard currently in place to capture the statistical process data for exchange between modeling tools. Manual methods for extracting process information from one model and inserting it into another model are time consuming and error prone. The results of Document Shipyard Processes task of this project showed that the initial steps in plate processing were very similar at different shipyards. This task also showed that it is possible to accurately describe individual process steps and machine operations with a minimal set of parameters. There is hope that in the future a common process description language, such as PSL, could capture all of the required process information into a standard format for exchange between modeling tools.

7. Conclusions

This project successfully demonstrated that process simulation could be made available to a wide audience through the World Wide Web. A user with no specific training in process modeling or simulation could make use of the DESTINY web site to generate simulation models and statistical output. A more experienced user could easily experiment with different configurations or rates to quickly generate throughput comparisons. It is expected that one of the most beneficial outcomes of this overall task will be the use of the DESTINY web site for rough capacity calculations of different plate cutting configurations.

The generic, reconfigurable models provided through the DESTINY web interface have practical limitations. The current site only provides a limited number of machine types and processes. In order to provide additional options, the complexity of the automatic model configuration process would be greatly increased. The QUEST software used to perform the discrete event simulation uses 3D graphics for model layout and display. The web site uses default graphical representations of machines and arranges them in a single layout. There are no tools provided for rearranging the 3D layout. Enabling an interface to QUEST's inherent 3D tools through the web site would be a difficult task. For complex process modeling tasks, and greater control over the model layout and geometry, it would be more straightforward to forgo the generic web interface and to build models directly using simulation software.

The use of process modeling and discrete event simulation in the shipbuilding process requires a significant effort, especially in the early phases. The software tools used for process simulation are not as easy to use as typical office productivity applications. These tools require extended time and dedicated use to become proficient. The task of collecting data and capturing the "as-is" process is also difficult.

For those shipbuilding organizations that make the investment to adopt process modeling, and support dedicated internal resources to do this work, there is long term benefit and return. Internal ownership of process models enables rapid updates to account for corrections or enhancements. This is more difficult to do when a model is developed and maintained by an outside agent. Assumptions and default values that must be built in to a simulation model are more likely to be correct if the model is built by those who also build the actual product. Having staff who are knowledgeable in simulation, and who are actively engaged in the shipbuilding process, also leads to the discovery of new application areas for simulation. After the initial learning curve has been ascended, process modeling can be applied in a cost effective manner to new problems. The long term increases in efficiency and productivity resulting from process modeling should far outweigh the cost of developing and maintaining this capability.

For Electric Boat it has been very beneficial to develop experience with process modeling tools through work on this project. The use of QUEST, with its 3D graphical presentation, was a natural fit with the exclusive use of solid modeling for CAD design work and the extensive use of electronic mockup visualization. Electric Boat has a large

enough staff to support a group with skills in modeling and simulation and to develop expertise in the use of discrete event simulation software. The internal development of process models for this project has given greater visibility to the use of process modeling within the company. A number of applications have been identified as potential candidates for future modeling and simulation work. The expected result will be analysis and improvement of other processes across the organization. The long term benefits of this NSRP project should be seen in improvements and advances well beyond the scope of the original task.

The exchange of discrete event simulation models and process data between different organizations and the interoperability of simulation software is a difficult problem. Although many different simulation software packages share similar process definition and modeling features, the actual models are stored in proprietary formats. There is no standard format for the expression of a process model in neutral file. There is no automatic method of exchanging process models between different simulation software applications. A joint effort of government, industry, and academia is underway to define a Process Specification Language (PSL).¹ The goals of the PSL effort include the definition of a standard format for capturing process information, and a methodology for enabling the exchange of process models between applications. The use of this standard format and methodology have already been demonstrated in a process model exchange prototype. It may be years before PSL or some other standard is widely adopted and available, but progress is being made in this area.

¹ For information on PSL see <http://www.mel.nist.gov/psl/>

8. Recommendations

It is recommended that a follow-on effort be undertaken to further pursue the process model component library approach developed under this task. The commonality of processes found for initial plate processing between different shipyards indicates that there is value in refining the models of these process steps. The library approach should be redirected so that the components are accessible from inside a particular process simulation software package rather than through a generic web interface. The use of a generic web interface imposes practical limitations on the control of 3D model geometry and layout. This provides easy access at the expense of model detail and complexity. If the library of reconfigurable components were used exclusively from within the simulation software these limitations could be avoided. The library of process steps and machines could be used to quickly assemble larger composite models. With the native tools of the simulation software, these larger models could then be refined, and specific details added. The process model library would function like a standard parts library in CAD, which enables applications to quickly build large arrangement models.

There is great potential benefit in the development of a standard for exchanging process models between different discrete event simulation software packages. A task should be established to prototype the use of the emerging Process Specification Language (PSL) for the exchange of process models that are specific to the shipbuilding domain. It is unreasonable to assume that different shipyards will select the same software tools for process modeling. If it were possible to accurately exchange process models, then multiple shipyards could begin to collaborate on, and share the cost of, the development of better models. This collaboration would be supported even between organizations using different modeling tools. Generic process model libraries could be built to simplify the development of large, complex models. The individual process components from these libraries could then be imported into any simulation software package that supported the exchange standard. The simulation software vendors would be motivated to adopt the standard, just as the CAD software vendors have adopted such formats and standards as DXF, VRML, IGES, and STEP. The development of a standard such as PSL would generate wide industry support, not only from shipbuilding, but also from the petro/chemical, automotive, aircraft, and consumer goods areas.

Appendix A

Process Parameters

Plate Treatment

<u>Equipment/Process</u>	<u>Required Parameters</u>
Material Receipt And Conveyor Load	Material Receipt Area (dimensions) Gantry Move Times (distances, constant or distribution) Forklift Move Times (distances, constant or distribution) Other Material Transporters (distances, constant or distribution) Labor (# and dept)
Material Conveyors	Capacity (size, length and width) Speeds (constant, variable)
PreDry	Dry Time (feed rate ft/min, affects conveyor speed) Size of Unit (length, width)
Blast	Capacity (size up unit) Blast Rate (based upon length ft or area sq ft) Speed Constant or Distribution based upon variability of feed rate (Conveyor Speed) Labor (# and dept)
Buffer	Capacity equals space between Blast and Paint Machine
Paint & Dry	Capacity (size of unit) Paint Rate (based upon length or area, affects conveyor speed) Dry time (type of paint, temperature) Labor (# and dept)
Buffer	Capacity equals space between Paint Machine and end of Conveyor (Conveyor Speed)
Part Removal	Part Distribution Rules (where to send material) Gantry Move Times (constant or distribution) Other Material Transporter Times (distances, constant or distribution) Labor (# and dept)

NOTE: For all machines need MTBF, downtime, repair time (associated labor).

Material attributes: length, width, thickness, material type

Shape Treatment

<u>Equipment/Process</u>	<u>Required Parameters</u>
Shape Receipt	Load rules (blast conveyor, bypass conveyor (nonferrous)) Load Conveyor Time (gantry, forklift) Labor (# and Dept)
Blast	Blast Rate (based upon length ft or area sq ft) Speed Constant or Distribution based upon variability of feed rate (Conveyor Speed) Labor (# and dept)
Buffer	(based on conveyor space)
Conveyor Move	Conveyor rules (parts to machines including failures, crossover rules) Conveyor Speed.
Vertical Band Saw	Cut time (Cut rate x # of cuts, Cut rate = Cut Speed x Cut length) Labor (# and dept)
IronWorker	Cut time (Cut rate x # of cuts, Cut rate = Cut Speed x Cut length) Labor (# and dept)
Coper/Notcher	Cut time (Cut rate x # of cuts, Cut rate = Cut Speed x Cut length) Labor (# and dept)
Marking	Marking Time (# of parts, amount of data, marking method) Labor (# and dept)
Part Removal	Part Distribution Rules (where to send parts) Move Times (forklift, gantry, manual, etc) Labor (# and dept)

NOTE: For all machines need MTBF, downtime, repair time (associated labor).

Shape attributes: length, width, thickness, material type, shape type, number of nested parts, length of cuts, number of marks, length of mark

Plate Cutting

<u>Equipment/Process</u>	<u>Required Parameters</u>
Plate Receipt	Plate Receipt Area (dimensions) Gantry Move Times (distances, constant or distribution) Transfer Car Speed (distances, constant or distribution) Other Transporters Times (distances, constant or distribution) Labor (# and dept)
Buffer	Plate Storage Area Conveyor Space
Plate Move	Gantry Move Times (constant or distribution) Distances to Cutting Tables Conveyor (distances, speed) Plate Move Rules (which cutting table is used) Labor (# and dept)
Cutting Table	Table rules (# plates, cutting heads, operation) Setup time (constant or distribution) Processing Time (Cut rate times cut length) Cut rate (cut speed based upon plate thickness) Labor (# and dept) Additional Ops (piercing)
Waterjet Cutting Table	Setup time (constant or distribution) Processing Time (Cut rate times cut length) Cut rate (cut speed based upon plate thickness) Labor (# and dept) Additional Ops (piercing)
Marking	Rate = Mark speed times no. marks (mark length) Number of Parts to be Marked Labor (# and dept)
Part Removal	Part Distribution Rules (where to send parts) Gantry Move Times (constant or distribution) Remnant Cart Rules Remnant Cart Speed Labor (# and dept)

NOTE: For all machines need MTBF, downtime, repair time (associated labor).

Plate attributes: length, width, thickness, material type, number of nested parts, length of cuts, number of marks, length of mark

Shape Cutting

<u>Equipment/Process</u>	<u>Required Parameters</u>
Shape Receipt	Shape Receipt Area (dimensions) Load Roller Table/Conveyor Time (gantry, forklift travel times) Labor (# and Dept)
Buffer	(based on roller/conveyor space)
Conveyor Move	Conveyor rules (parts to machines including failures, crossover rules) Conveyor Speed
Vertical Band Saw	Cut time (Cut rate x # of cuts, Cut rate = Cut Speed x Cut length) Labor (# and dept)
Ironworker	Cut time (Cut rate x # of cuts, Cut rate = Cut Speed x Cut length) Labor (# and dept)
Coper/Notcher	Cut time (Cut rate x # of cuts, Cut rate = Cut Speed x Cut length) Labor (# and dept)
Marking	Marking Time (type of marking, # of marks, marking lengths) Labor (# and dept)
Part Removal	Part Distribution Rules (where to send parts) Move Times (forklift, gantry, etc) Labor (# and dept)

NOTE: For all machines need MTBF, downtime, repair time (associated labor).

Shape attributes: length, width, thickness, material type, shape type, number of nested parts, length of cuts, number of marks, length of mark

All shapes can go to the band saw, only angle and flat bar will go to ironworker. Coper/notcher is used only on angle and flat bar.

Appendix B

Component Process Models

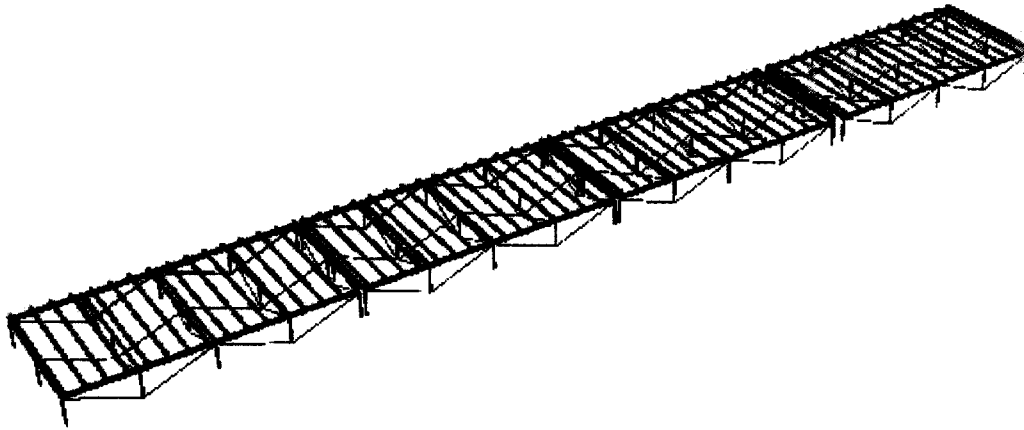


Figure B-1. Plate Conveyor

A conveyor transports objects at a fixed speed, and can either accumulate objects along its length or feed them into a buffer.

Principal Parameters

Conveyor Speed

Conveyor Length

Input

Plate

Output

Plate

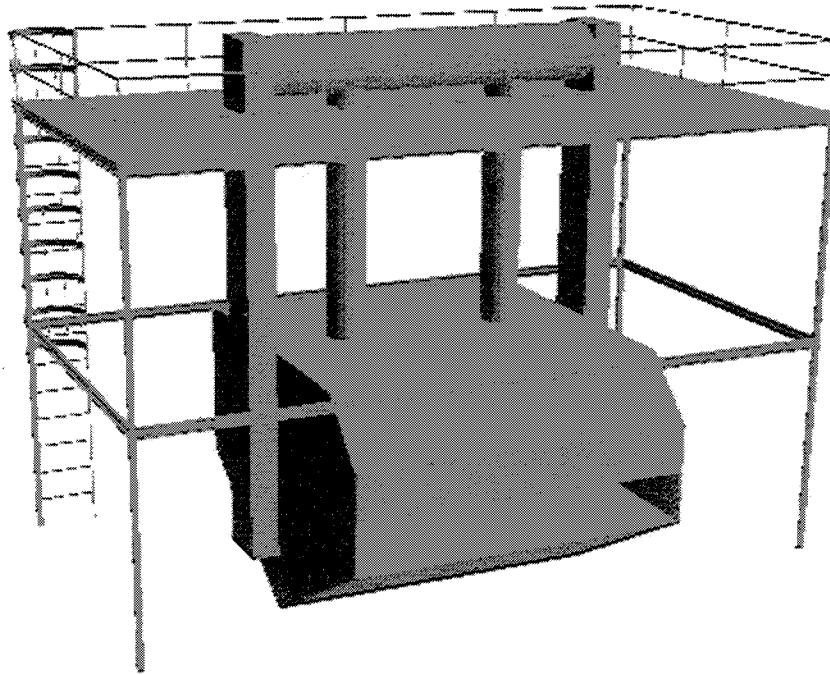


Figure B-2. Sand Blasting Machine

A sand blasting machine processes objects at a fixed speed based on the blasting rate and the type of grit used. Output from the blasting machine may be portrayed as a different part than input for visual effect (i.e. color change).

<u>Principal Parameters</u>	<u>Input</u>	<u>Output</u>
Machine Speed	Plate	Plate
Length of Plate		

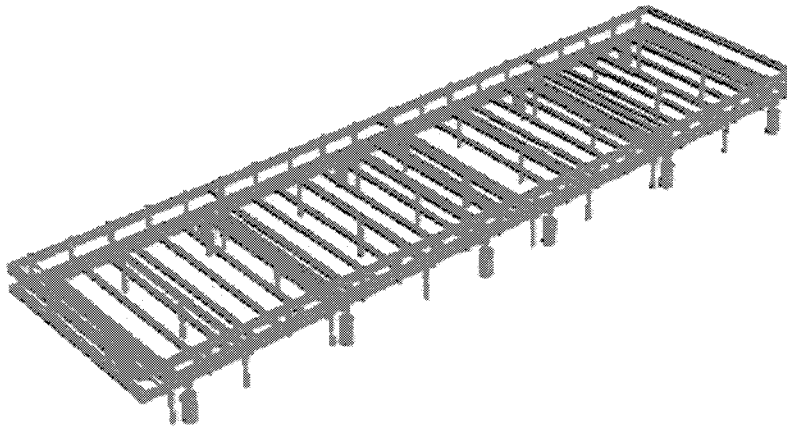


Figure B-3. Plate Marking Machine

A plate marking machine processes a plate over time, depending on the quantity and length of layout and identification markings.

<u>Principal Parameters</u>	<u>Input</u>	<u>Output</u>
Machine Marking Speed	Plate	Plate
Quantity of ID Marks on Plate		
Length of Layout Lines on Plate		
Setup/Calibration Time		

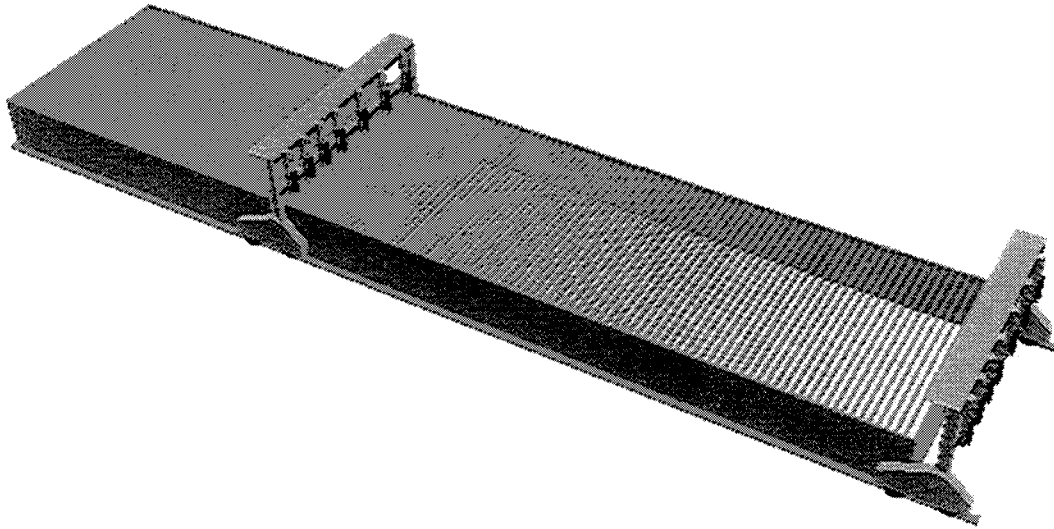


Figure B-4. Plasma Cutter with table

A cutting machine processes a plate over time, depending on the cut length of all parts. It converts a single plate into parts and scrap.

<u>Principal Parameters</u>	<u>Input</u>	<u>Output</u>
Machine Cutting Speed (Function of material type & thickness)	Plate	Parts (new parts & scrap)
Length of Cuts on Plate		
Material Type for Plate		
Thickness of Plate		
Plate Marking Time (When marking option selected)		
Setup/Calibration		
Part Removal		

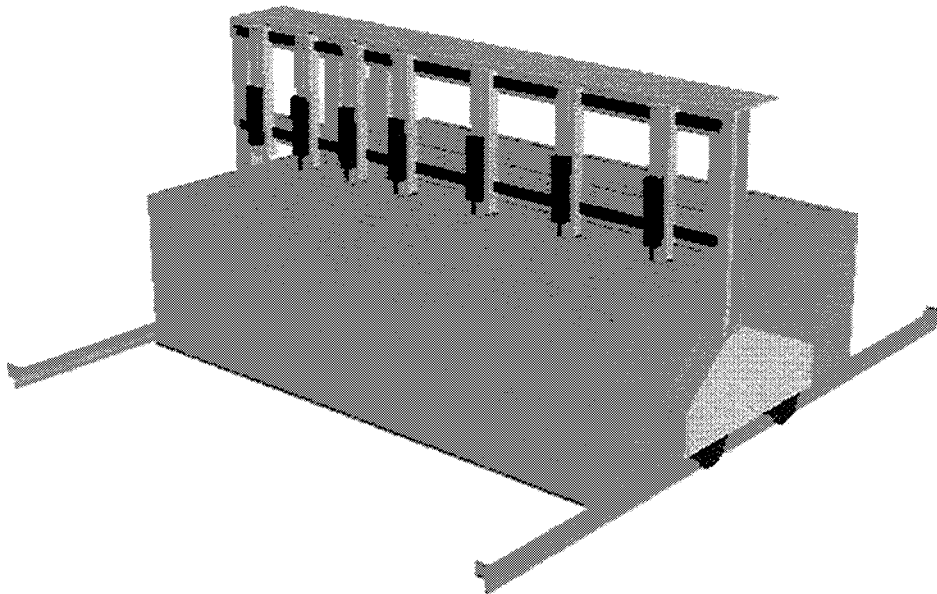


Figure B-5. Water Jet Plate Cutting Machine

A cutting machine processes a plate over time, depending on the cut length of all parts. It converts a single plate into parts and scrap.

<u>Principal Parameters</u>	<u>Input</u>	<u>Output</u>
Machine Cutting Speed (Function of material type & thickness)	Plate	Parts (new parts & scrap)
Length of Cuts on Plate		
Material Type for Plate		
Thickness of Plate		
Plate Marking Time (When marking option selected)		
Setup/Calibration		
Part Removal		

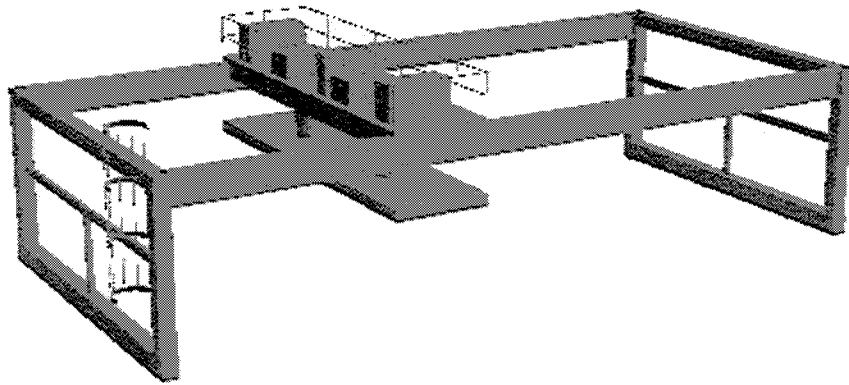


Figure B-6. Magnetic Overhead Gantry crane for plates

A gantry moves parts at a fixed speed between any combination of conveyors, buffers, marking, and cutting machines.

Principal Parameters

Input

Output

Machine Speed

Plate/Parts/Scrap

Plate/Parts/Scrap

Distance of Travel

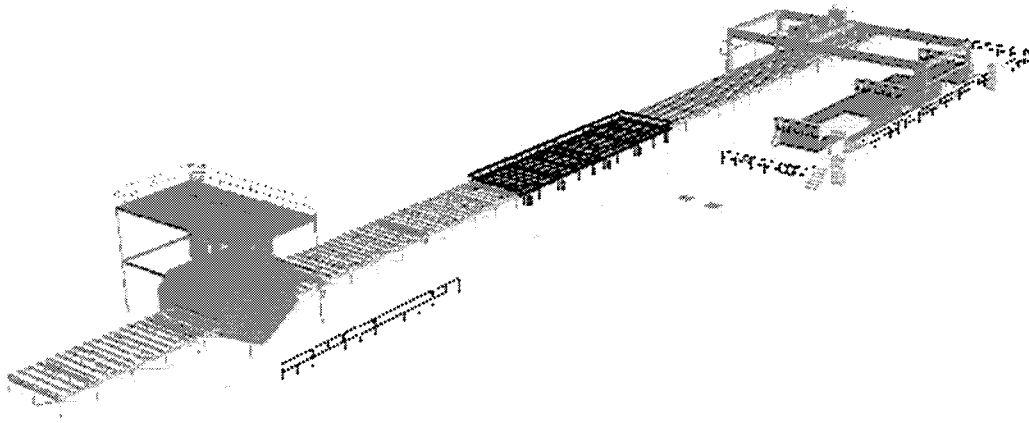


Figure B-7. Model combining several component machines.

This represents one particular layout and arrangement of components to form a processing line. This model includes a blasting machine, a marking machine, two cutting machines, conveyors, and a gantry crane.

<u>Principal Parameters</u>	<u>Input</u>	<u>Output</u>
Component Layout	Plate	Plate/Parts/Scrap
Equipment Required		
Material Input Schedule		

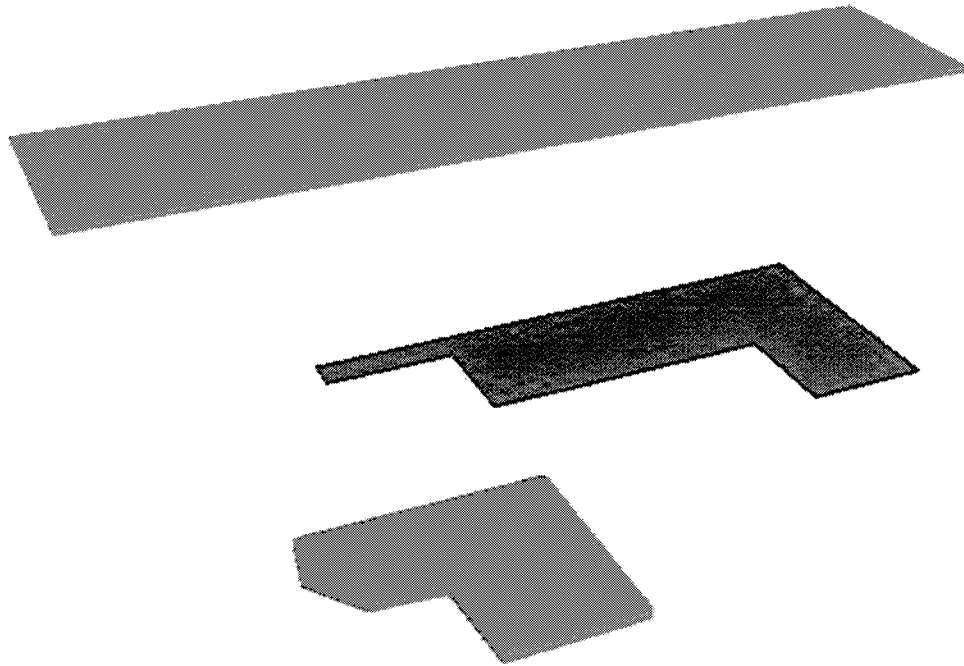


Figure B-8. Product Geometry Representations
(Top to Bottom; Whole Plate, Scrap Material, Cut Piece)

Source material, plate, is delivered to the simulation as input according to either a specified schedule or as a function of the total material required. Piece part and scrap output is generated based on the same schedule or distribution information.

Principal Parameters

Plate:

Material Type

Dimensions

Piece/Scrap:

Number of Pieces

Dimensions

Appendix C

Electronic Media Supplements

NSRP (4-98-3) Development of a Shipbuilding Process Modeling Database

This appendix is comprised of two computer files which are provided on a separate ZIP disk. The file, Complete_Destiny_1.mdl, contains a QUEST model of a simple plate processing line. This model can be viewed and exercised using the QUEST software. The second file, Destiny_Movie.avi, contains an electronic movie sequence of the process line in the above QUEST model. This movie can be played on a PC by double clicking on the file icon. If the ZIP disk containing these files is not provided with the text of this report, the files can be obtained by contacting:

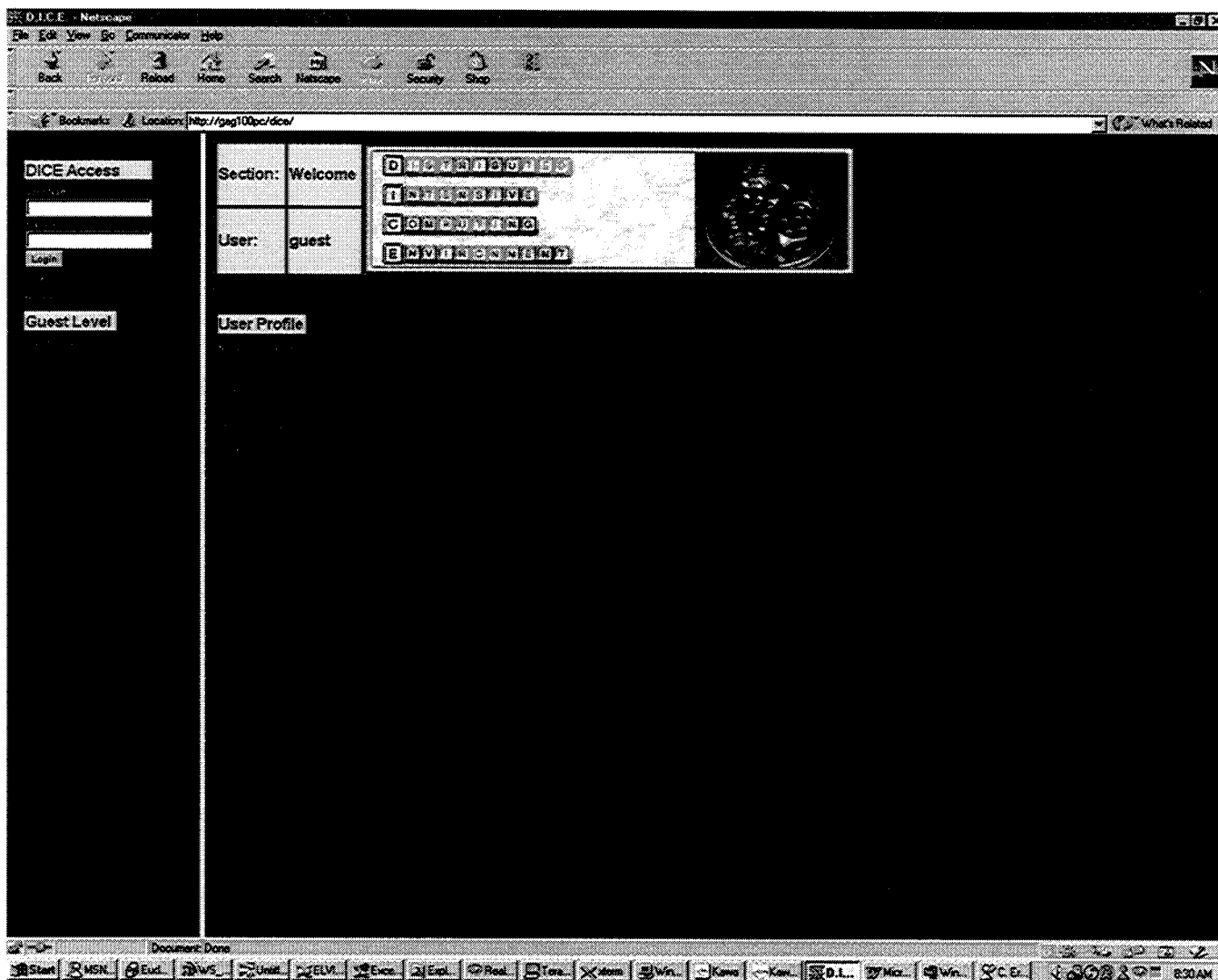
Ken Fast
Electric Boat Corporation
75 Eastern Point Road
Groton, CT 06340
(860) 433-6432
kfast@gdeb.com



Appendix D

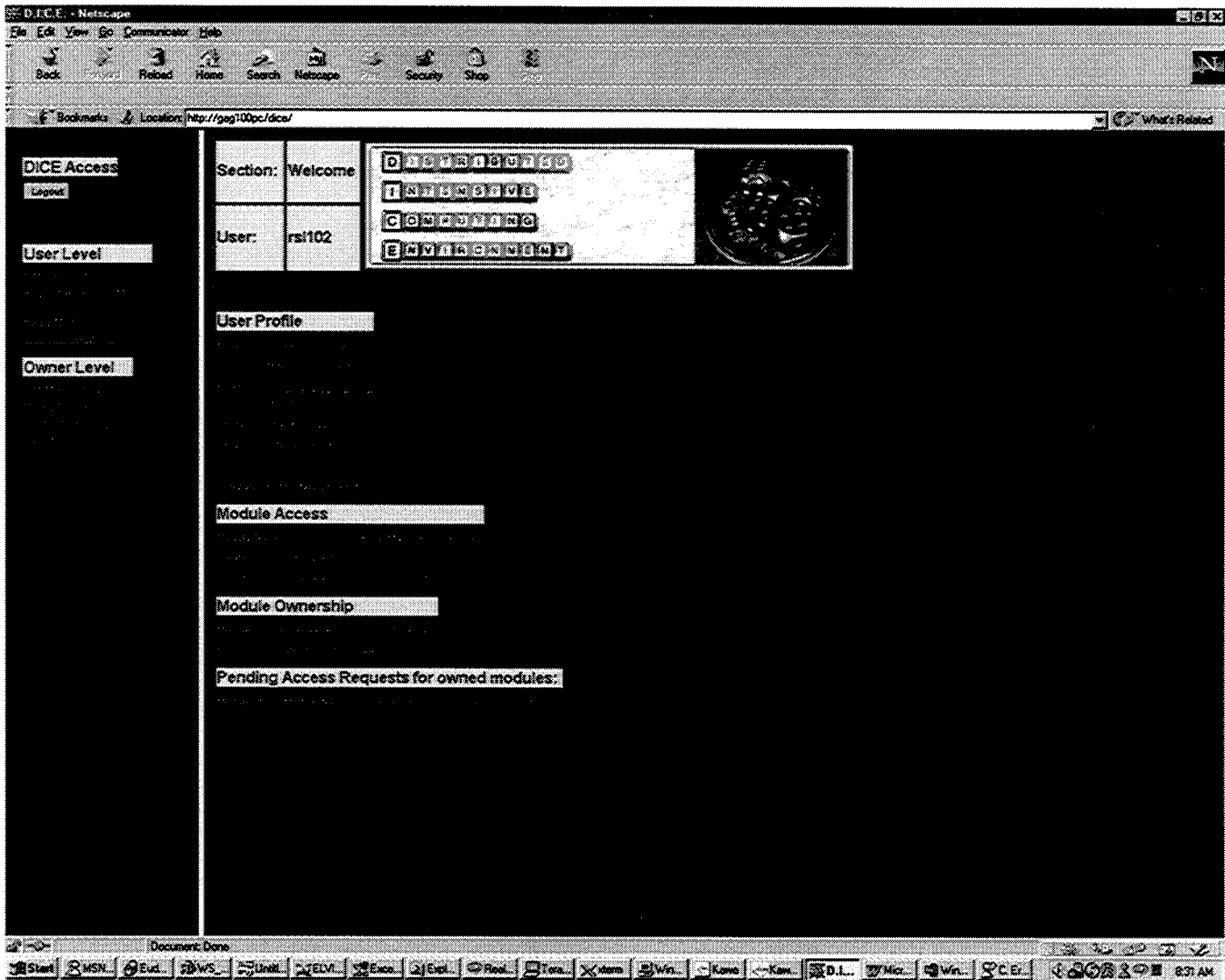
WWW Site On-line User Instructions

General Page Layout



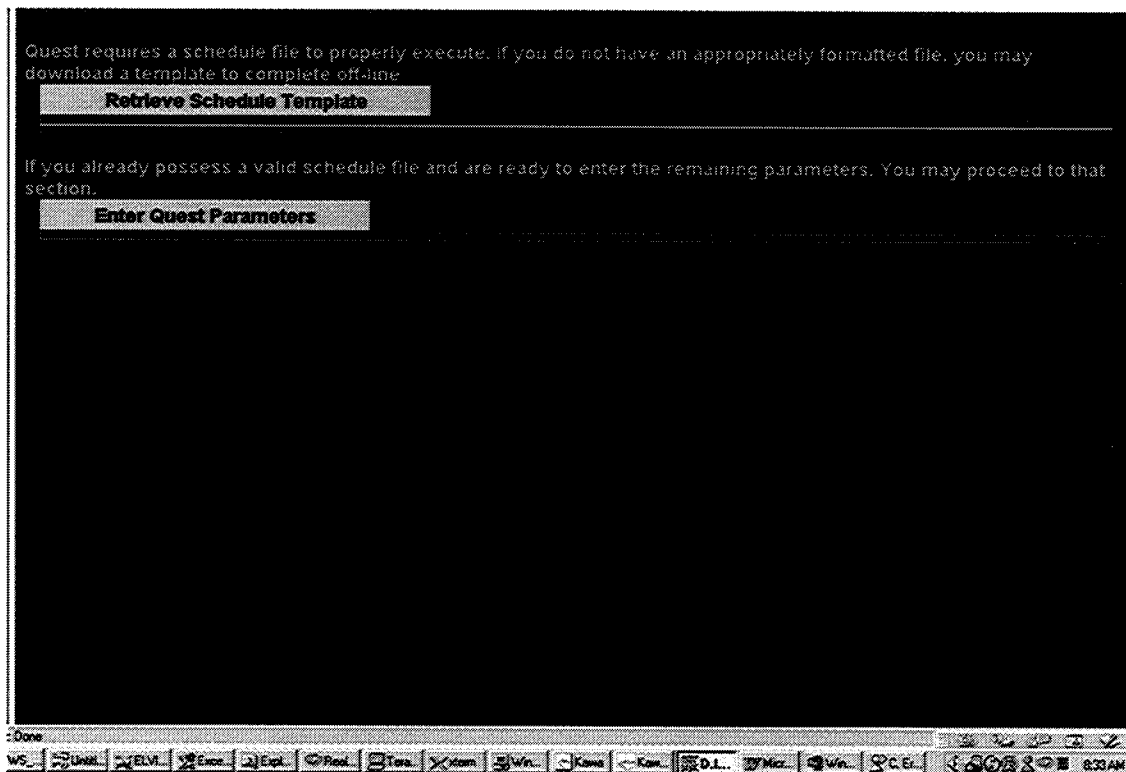
Initial presentation of DICE to a user.

User Options



After login, the left frame contains a menu of all options available to the current user. The right contains the current profile for this user. For the remainder of the session the left menu remains available to the user.

Running the BCL Module

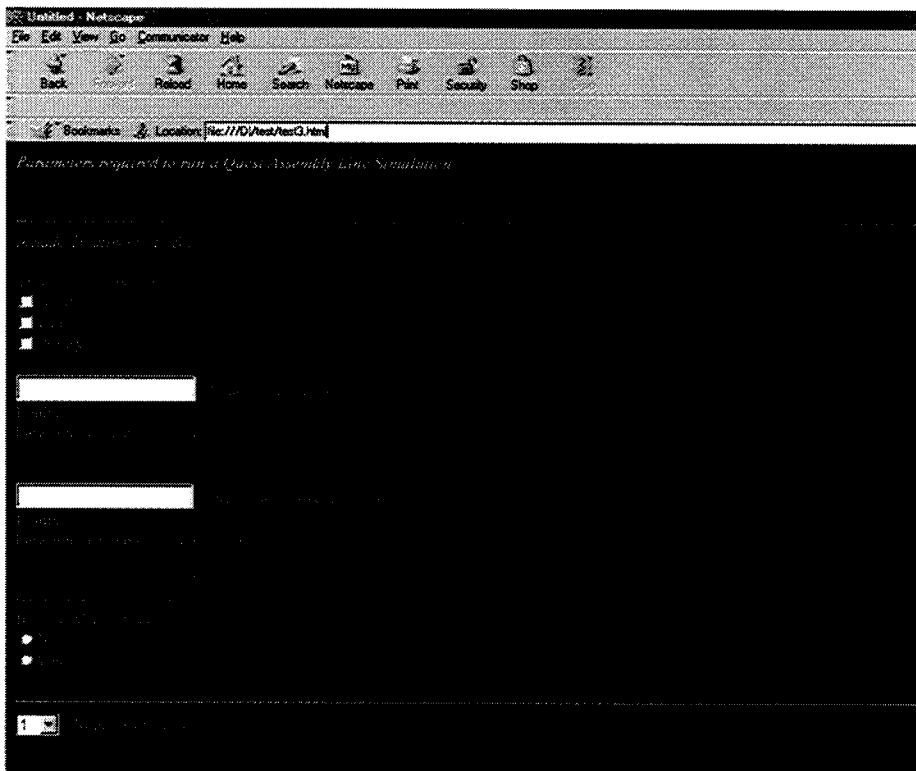


The user may choose to download an Excel template to assist in the building of a valid schedule file, or proceed to enter the required parameters. Refer to the complete list of Simulation Parameters.

Example



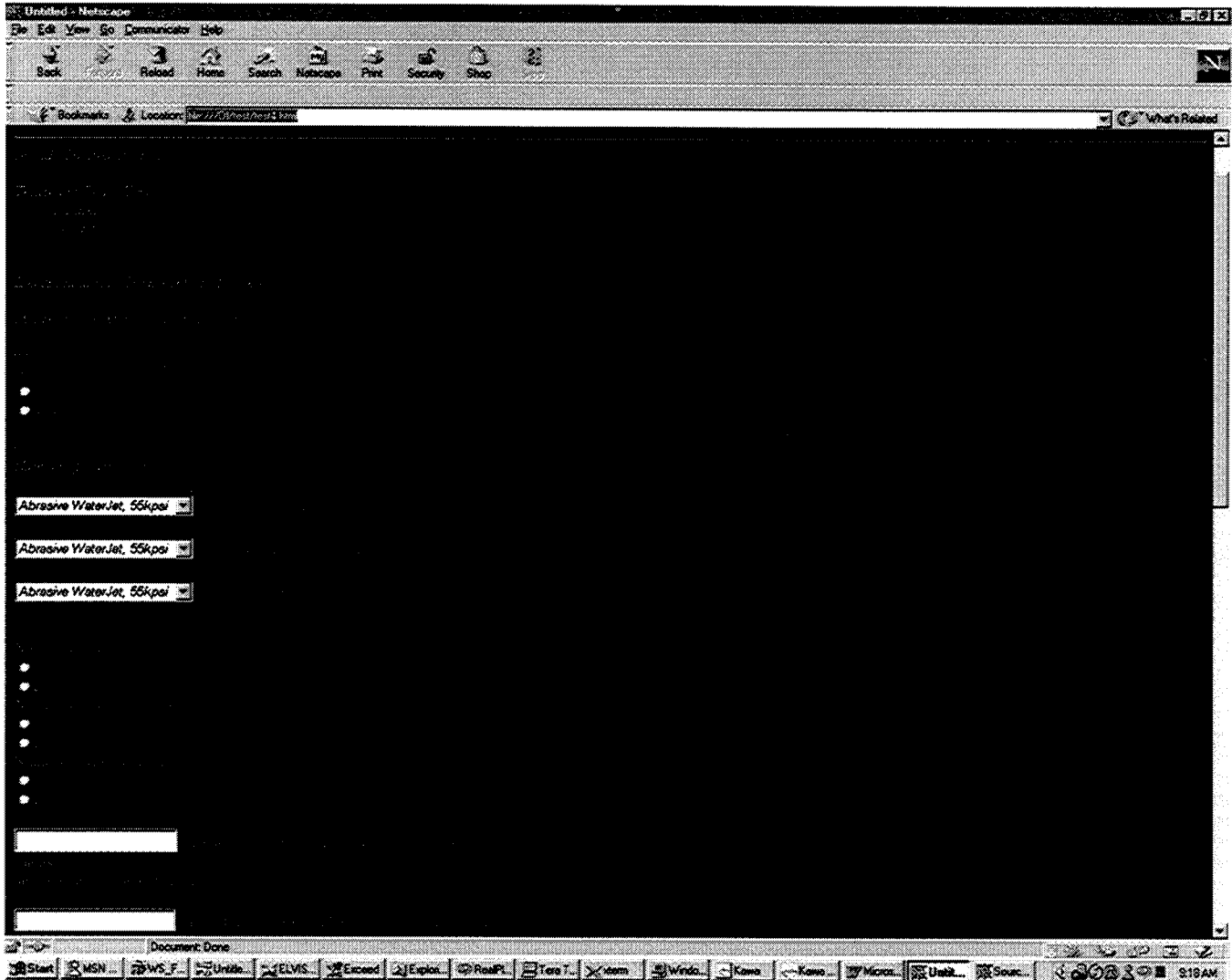
This is the first page presented to the user for entering inputs. The BCLServlet generates each html document dynamically. If a required question is not answered successfully it is repeated, along with an error message, until the user provides a valid answer. No question dependent on an unanswered or invalid question is displayed until a valid answer is provided.



NSRP (4-98-3) Development of a Shipbuilding Process Modeling Database

As questions are answered, the system builds the next appropriate page, dependent on:

- 1) Successful validation of provided answers.
- 2) Dependencies between questions
- 3) Properties of the new questions



NOTE: If there are multiple instances to be answered for a single question, e.g. one question repeated for each of the cutters specified, all instances are grouped together.

Simulation Parameters

1. Treatment Variables
 - a. Treatment
 - b. Treatment_Predry
 - c. Treatment_Blast
 - d. Treatment_Paint
 - e. Treatment_Linespeed
 - f. Treatment_Distance
2. CNC Marking variables
 - a. CNC_Marking
 - b. CNC_Mark_LoadTime
 - c. CNC_Mark_IDMarkTime
 - d. CNC_Mark_LayoutMarkTime
 - e. CNC_Mark_Distance
3. Cutting
 - a. Cutters
 - b. Cut_LoadTime{1,2,3,4} e.g. Cut_LoadTime1 is load time for first cutter, Cut_LoadTime2 is load time for second cutter.
 - c. Cut_MachineType{1,2,3,4}
 - i. Laser,3KW
 - ii. Laser,6KW
 - iii. Plasma,30amp
 - iv. Plasma,50amp
 - v. Plasma,100amp
 - vi. Plasma, 200amp
 - vii. Abrasive WaterJet, 55kpsi
 - d. Cut_MachineNumHeads{1,2,3,4}
 - e. Cut_MaxSteelThickness{1,2,3,4}
 - f. Cut_MaxAluminumThickness{1,2,3,4}
 - g. Cut_KittingDistance {1,2,3,4}
 - h. Cut_ScrapDistance {1,2,3,4}
 - i. Cut_IDMarkTime{1,2,3,4}
 - j. Cut_LayoutMarkTime{1,2,3,4}
4. Run Characteristics
 - a. Run_For
 - b. Capacity_TotalHours
 - c. Schedule_ShiftsPerDay
 - d. Schedule_HoursPerShift

Appendix E

DICE System Architecture

System Overview

Distributed Intensive Computing Environment (DICE) is a networked software system that manages a distributed library of computing intensive modules. DICE allows users to submit run requests, which are logged, for the computing intensive modules through an interactive web-site. A Distribution Hub continually monitors the request log, checking for new runs to be processed. The Hub also manages a network of Worker machines on which the actual computing intensive modules reside. As it receives run requests, the Hub distributes each new run to a networked Worker, based on ability to execute the requested module, current availability and performance estimates. The Worker executes the requested module using the provided inputs. Upon completion, the Worker returns any results to the Hub. The Hub then notifies the user by email that his or her run is complete. The user may then return to the web site to download those results.

Access and Security

Access

Before a user may access any resources available through DICE, he must:

1. Create a user account to allow password authentication on subsequent visits.
2. Request access to a specific module.
3. Wait until the module owner grants authority to execute runs of that module.

Security Restrictions

- No user has access to another user's account, including profile information, run inputs and results.
- Only a module owner or the DICE administrator can add and configure a worker the DICE network for a particular module.
- A module owner can add capabilities to a worker only for his modules.
- The java security model governs all inter-machine communication.

DICE Architecture

Figure E-1 shows the overall system architecture of DICE. Figure E-2 outlines the flow of control between various components of the system during the processing of a single run. Figure E-2 also outlines the effects on a module status based on various events once a module run is initiated.

Worker Configuration

Software

- Quest must be successfully installed on the machine.
- Perl must be successfully installed on the machine.
- A batch file invoking first ParseTemplates.pl and then Quest with ParseTemplates.pl output must be configured and installed successfully on the machine.
- The Worker process must be installed and started successfully on the machine.

Directory Structure

- C:\DENEb is the root directory for quest installation
- C:\DENEb\inputs receives input files from server whenever a run is requested. They are deleted locally upon completion of run
- C:\DENEb\outputs holds output files {including intermediate output from parseTemplates.pl} from Quest run for pickup by server. They are deleted locally once retrieved by the server.

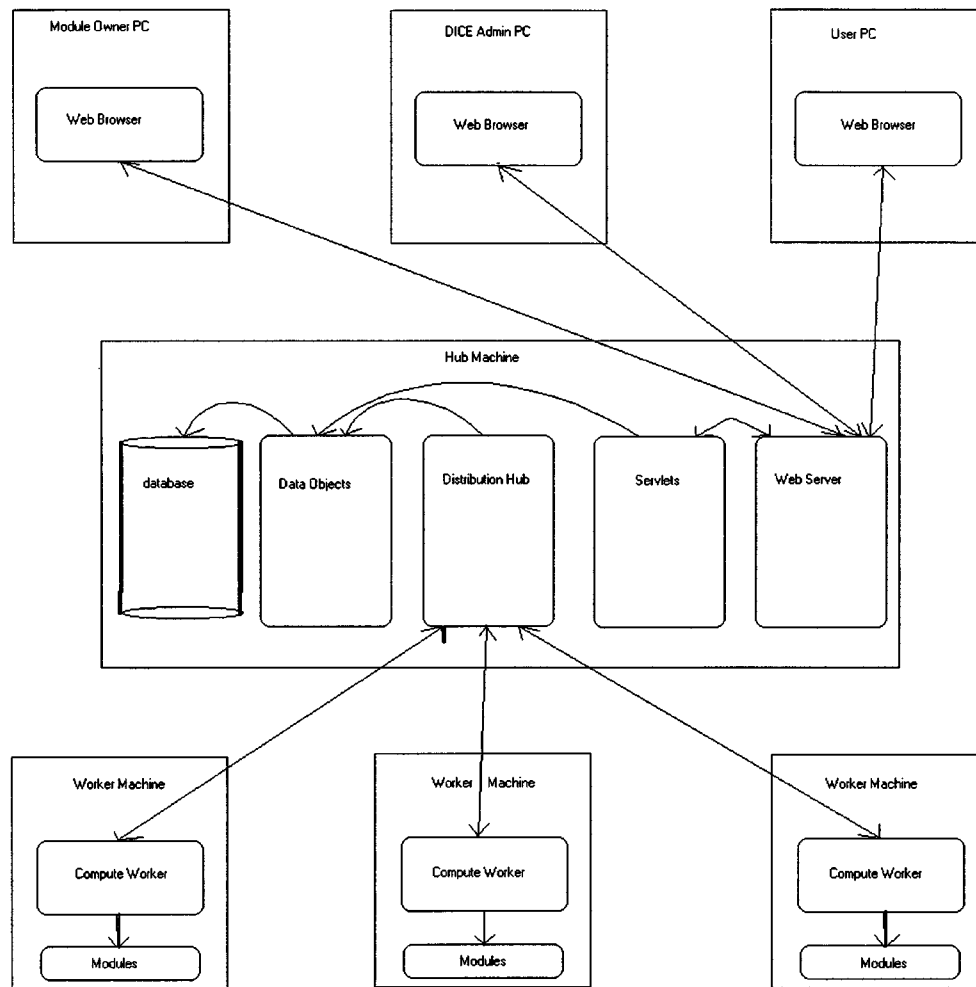


Figure E-1. Overall DICE System Architecture

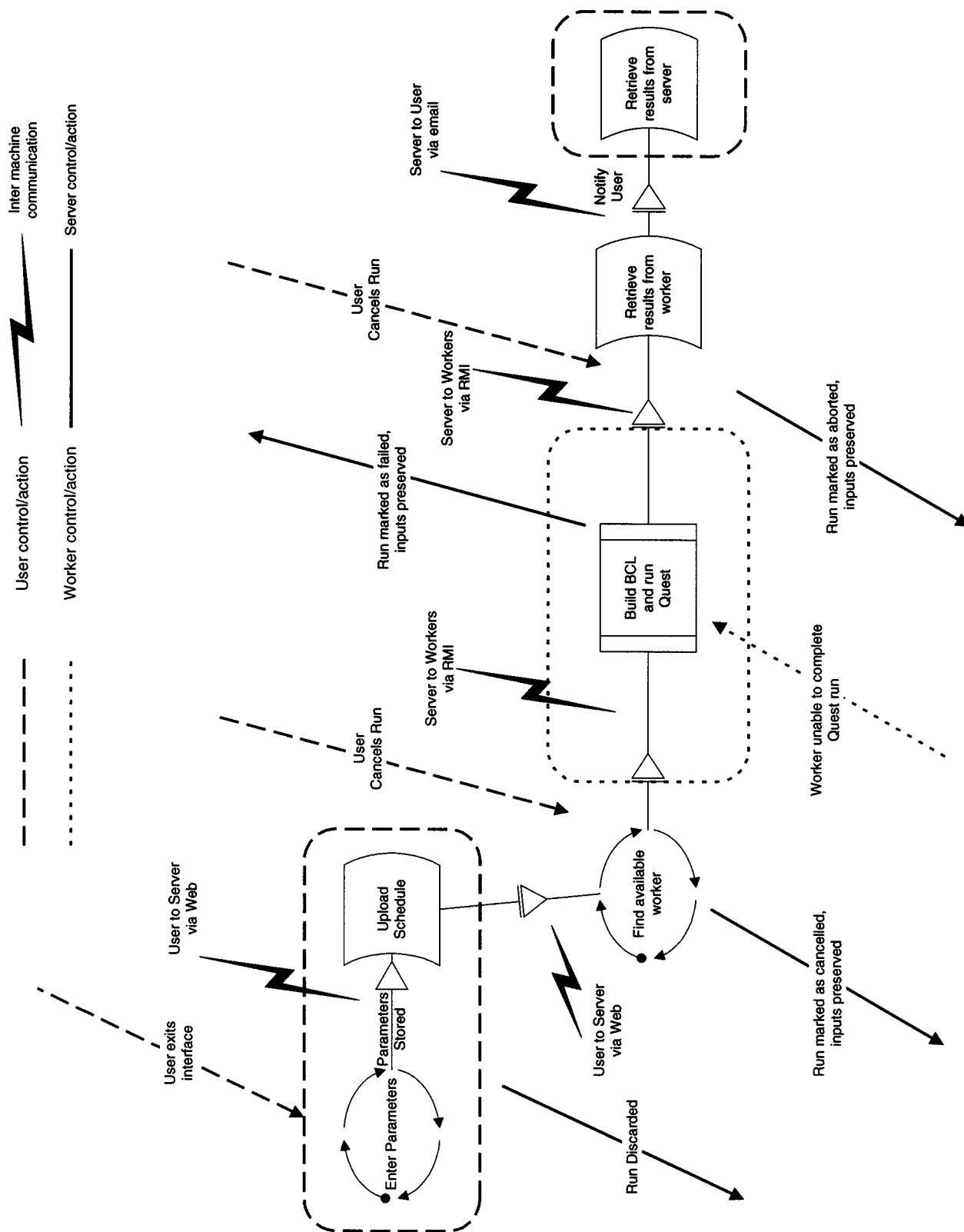


Figure E-2. DICE Flow Control

Dynamic HTML Page Creation

- HTML is 4.0 compliant. For further information on the HTML4.0 specification, please refer to <http://www.w3.org/MarkUp/>
 - All style is applied using Cascading Style Sheets.
1. Answered Questions
 - a. Any question with available valid values renders as standard static text.
 - b. A question with multiple values renders using `<DL> <DD> Description </DD> <DT> value1 </DT>...<DT>valueN</DT> <DL>` tags.
 - c. A question with an associated unit of measure renders with the unit of measure appended after the value.
 2. Pending Questions
 - a. The description style is defined with the `` tag.
 - b. Any question awaiting a value renders as a form element.
 - c. Any question with an associated unit of measure renders with the unit of measure appended.
 - d. Any question with more than one instance renders with the instance appended, before the unit of measure if applicable.
 - e. Any question awaiting an answer renders according to the type of value it expects.
 - i. A question expecting a single value, *PER INSTANCE* of the question, renders with an `<INPUT ... type = "text">` tag.
 - (1) Any limits or conditions associated with a question are rendered on a new line directly below the question.
 - ii. A question expecting multiple selections from a predetermined list, *PER INSTANCE* of the question, renders with an `<INPUT ... type="checkbox">` tag.
 - iii. A question expecting a single selection from a predetermined list renders according to the number of available options:
 - (1) Less than 3 options `<INPUTtype="radio">` tag.
 - (2) Greater than 3 options `<SELECT ><OPTION>value1</OPTION>...<OPTION>valueN</OPTION>`.
 3. Invalid questions
 - a. Any question provided an invalid answer renders as II with the appending of a standard error message.
 - b. The style of the error message is defined with the `` tag.
 4. Category transitions
 - a. Each transition between question categories is indicated with a `<HR/>`.

Additional copies of this report can be obtained from the
National Shipbuilding Research and Documentation Center:

<http://www.nsnet.com/docctr/>

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